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Araştırma Makalesi
Research Article

Color detection based object discrimination design and development

Renk Algılama Temelli Nesne Ayrımı Tasarımı ve Geliştirilmesi

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Abstract: The rapid advancement of technology has led to a significant increase in the demand for mechanical power. Mechanical power has become a crucial component of contemporary technology by reducing human labor, minimizing error margins, and increasing production capacity. In this context, robots that can be programmed for various purposes and perform specific functions are widely used in industrial applications. Specifically, robotic arms constitute one of the fundamental elements of industrial automation. This paper examines the applicability of a stationary robotic arm. The proposed system aims to enhance the speed, safety, and accuracy of processes such as product sorting, placement, and organization in factories. Fundamentally, a solution is proposed by integrating three main systems for this purpose: a conveyor belt system, a robotic arm, and image processing systems.

Keywords: Image processing systems, Product sorting, Placing and organizing, Factory automation, Robot arms, Conveyor belt

Özet: Teknolojinin hızla ilerlemesi, mekanik güce olan talepte önemli bir artışa yol açmıştır. Mekanik güç, insan emeğini azaltarak, hata paylarını en aza indirerek ve üretim kapasitesini artırarak çağdaş teknolojinin önemli bir bileşeni haline gelmiştir. Bu bağlamda, çeşitli amaçlar için programlanabilen ve belirli işlevleri yerine getirebilen robotlar endüstriyel uygulamalarda yaygın olarak kullanılmaktadır. Özellikle robot kollar, endüstriyel otomasyonun temel unsurlarından birini oluşturmaktadır. Bu makale, sabit bir robot kolunun uygulanabilirliğini incelemektedir. Önerilen sistem, fabrikalarda ürün ayırma, yerleştirme ve düzenleme gibi süreçlerin hızını, güvenliğini ve doğruluğunu artırmayı amaçlamaktadır. Temel olarak, bu amaç için üç ana sistem entegre edilerek bir çözüm önerilmektedir: bir konveyör bant sistemi, bir robotik kol ve görüntü işleme sistemleri.

Anahtar kelimeler: Görüntü işleme sistemleri, Ürün ayırma, Yerleştirme ve düzenleme, Fabrika otomasyonu, Robot kolları, Konveyör bant

1. Introduction

1.1. Motivation of the study

In contemporary settings, technological devices play a crucial role in every aspect of life, from production to consumption. To prevent adverse situations arising from human errors in the production phase and to ensure continuous and sustainable production without fatigue even during extended working hours, various systems have been developed. In this context, robotic arms are among the foremost examples. Robotic arms are frequently utilized in various factory departments, including production, packaging, transportation, and sorting. Systems integrated with image processing are designed to separate defective products in production or to sort a wide variety of products emerging from production. These systems can detect defective products more quickly and accurately than the human eye might miss. Additionally, they are preferred in sorting operations due to their higher carrying capacity compared to manual labor. This paper highlights a concept designed to identify and sort products in continuously operating factories as desired. The objective is to achieve a more accurate and faster sorting process. The proposed project consists of three main systems: a conveyor belt, a robotic arm, and an image processing system.

1.2. What is Object Discrimination Based on Color Detection?

The technique of sorting objects based on color without using a physical color sensor is referred to as object sorting based on color detection. This technique involves capturing images of objects moving along a conveyor belt using a camera or another visual device instead of a sensor. Subsequently, these images are analyzed using image processing algorithms to determine the color and shape of each object. As shown in Figure 1. a system with a robotic arm capable of sorting based on color and shape is proposed (Shah and Mishra, 2019).

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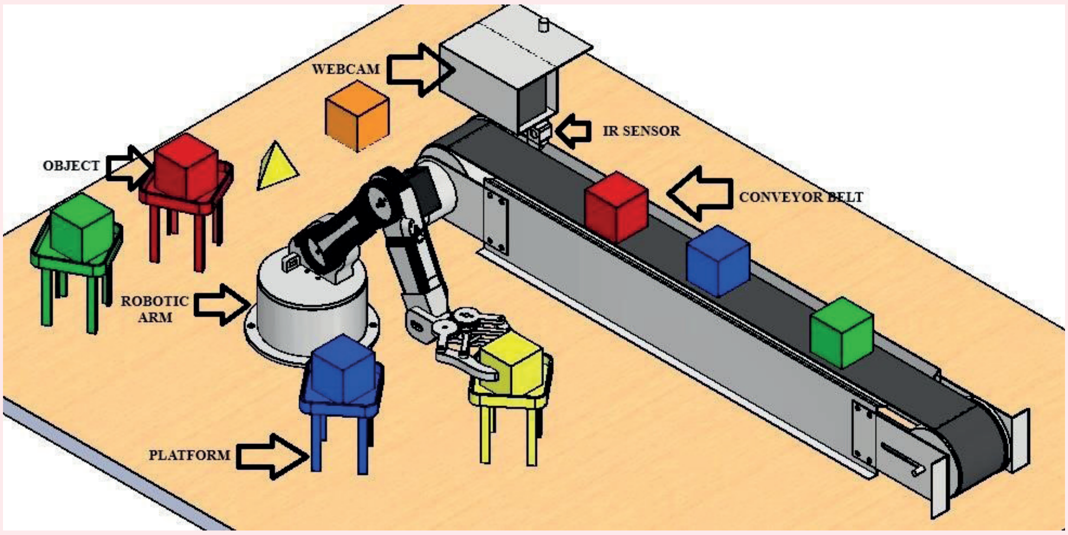

Figure 1. Color Detection Based Object Sorting

2. Material

- Microprocessor
- L293D
- DC Motor
- Servo Motors
- IR Sensor
- Analogue HD Camera
- Platform and Objects
- Power supply
- Carrying band
- Robot arm

2.1. L293D

The system that ensures the flawless and reliable operation of control boards or circuits in any structure is referred to as the L293D. When a current demand significantly higher than what the control board can provide is required, the use of motor drivers becomes crucial. This is necessary to prevent the control boards and circuits from burning out during operation. Motor drivers facilitate the smooth passage of current and energy delivery through effective current control. Notably, due to their ability to operate independently on both sides, they have the potential to drive two motors simultaneously in both directions.

2.2. Servo Motor

Servo motors are essential for enabling the movement of each joint in a robotic arm. A typical robotic arm consists of multiple joints. In the proposed project, SG90 micro servo motors are selected to facilitate two-axis movement of the robotic arm. These motors operate at a DC voltage range of 4.8 to 6 V. Due to their small dimensions, they are preferred for use in the gripper part of the robotic arm. The speed rating is 60 degrees per 0.1 seconds at 4.8V, and the stall torque is 1.8 kg·cm at 6V. The rotation angle ranges from 0° to 180°. For the primary movements of the robotic arm, MG996 model servo motors are recommended. This motor operates within a voltage range of 4.8 to 7 V and draws 500 mA of current. The reason for choosing this motor is its torque capability, which is 9.4 kg·cm at 4.8V and 11 kg·cm at 6V (Cong and Hanh, 2021)

2.3. IR Sensor

To detect when an object on the conveyor belt reaches the front of the robotic arm, an IR sensor is proposed. This sensor has a detection range of 2 to 30 cm, adjustable via an onboard potentiometer. It features a detection angle of 35 degrees and incorporates an LM393 comparator. Powered by 5V, the sensor provides a digital output, making it suitable for use in this project.

2.4. Platform and Object

The platform where objects will be placed is intended to be made of PLA material. The platform dimensions should be 70 mm in height, 40 mm in width, and 40 mm in length. It is envisaged that the platform will be designed with four different colors: red, blue, yellow, and green. As for the objects to be sorted, a cube made of PLA with dimensions of 40x40x40 mm has been selected. The cubes are also intended to be designed in four different colors: red, blue, yellow, and green. Additionally, it is planned to use two defective objects in the project, which could be an orange cube and a yellow triangular pyramid. The dimensions of these solid objects are illustrated in Figure 2. Furthermore, it is contemplated to use a platform with dimensions as seen in Figure 3.

2.5. Conveyor Belt

The planned conveyor belt is intended to be made of PVC material, with dimensions set at 80 mm in width, 600 mm in length, and 70 mm in height. A geared DC motor will be utilized for the movement of the conveyor belt. This geared DC motor operates at 12 V voltage and has a capability of making 37 revolutions per minute (RPM). The conveyor belt used adheres to the lengths illustrated in Figure 4. Additionally, a straight PVC belt is considered for use.

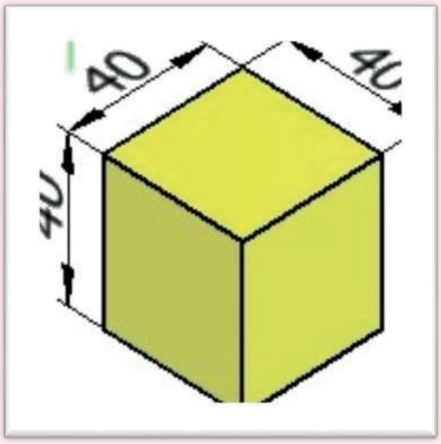

Figure 2. Object

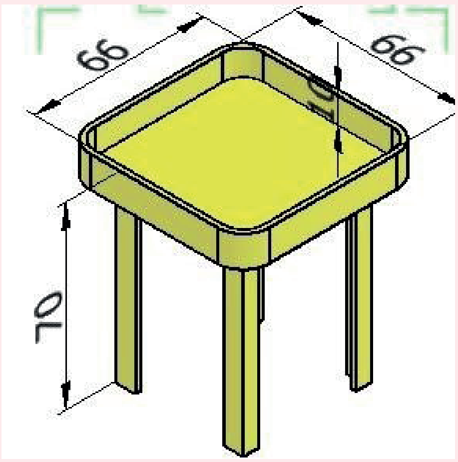

Figure 3.Platform

2.6. Robotic Arm

The envisaged robotic arm is intended to be manufactured from PLA material and to have five degrees of freedom (5 DOF). Five DOF implies that in a robotic arm, five separate axes of motion or points of articulation can move independently. As depicted in Figure 5., a robotic arm of the specified dimensions is proposed for use. Additionally, it is indicated that a robotic arm with 5 DOF will be employed, as shown in Figure 6. (Cong , 2021).

3. Image Processing Mechanism

The image processing system operates through two main components: color detection and shape recognition.

3.1. Color Detection

The color detection process is based on the RGB (Red, Green, and Blue) color model. In this model, the red, green, and blue components of each pixel are analyzed. The system is designed to detect four primary colors: red, yellow, blue, and green. The algorithm analyzes the RGB values of each pixel and compares them with predefined color threshold values (Szabó and Lie, 2012).

3.1.1 Color Thresholding

In this process, each color is defined within a specific range, and pixel values are analyzed accordingly. For instance, a particular threshold value is set for detecting the color red, and pixel values above this threshold are identified as red. Similarly, similar threshold values are determined for other colors (Szabó and Lie, 2012).

3.1.2 Histogram-Based Thresholding

This technique involves analyzing the color distribution of the image and determining the intensity of specific colors through histograms. A histogram is generated for each color, and color segmentation is performed based on predefined threshold values. This enables more precise and accurate detection of colors.

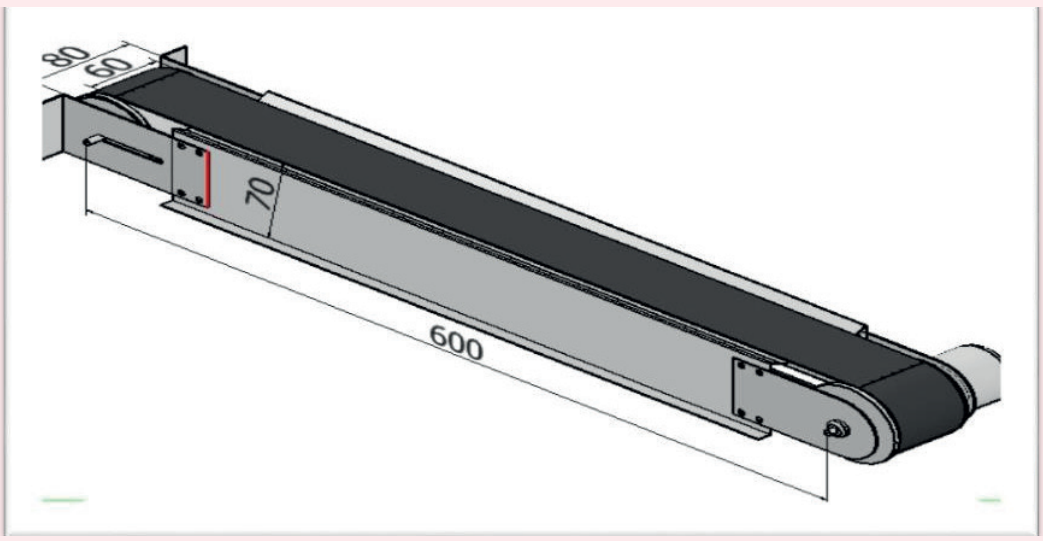

Figure 4. Conveyor Belt

3.1.3 Color Segmentation

In this step, pixels are grouped according to predefined threshold values, creating distinct regions with different colors on the image. Segmentation allows for the separation of specific color regions of the object and their identification. Through color segmentation, the object's color is accurately determined and relayed to the microcontroller.

3.2. Shape Detection

Shape recognition process ensures accurate identification of objects by analyzing their geometric features. In this system, the desired shape is determined as a cube, while the faulty shape is designated as a triangular prism. Shape recognition process consists of two main steps: edge detection and feature extraction.

3.2.1 Edge Detection

Edge detection is utilized to delineate the boundaries of objects. For this process, contour extraction algorithms such as Canny Edge Detection are employed. The Canny algorithm calculates the gradient of the image and defines gradients above a certain threshold value as edges. Consequently, prominent edges of the object are detected, and contours of the object are extracted based on these edges.

3.2.2 Feature Extraction

After edge detection, the shape of the object is analyzed using specific geometric parameters. In this process, parameters such as the number of corners, roundness, and surface features of the object are computed. For instance, a cube has six faces and eight corners. By extracting these characteristics, it is determined whether the object is a cube or not. Similarly, faulty shapes like triangular prisms can also be identified using these parameters.

3.2.3 Analysis of Geometric Parameters

Specific geometric parameters of the object are comput-

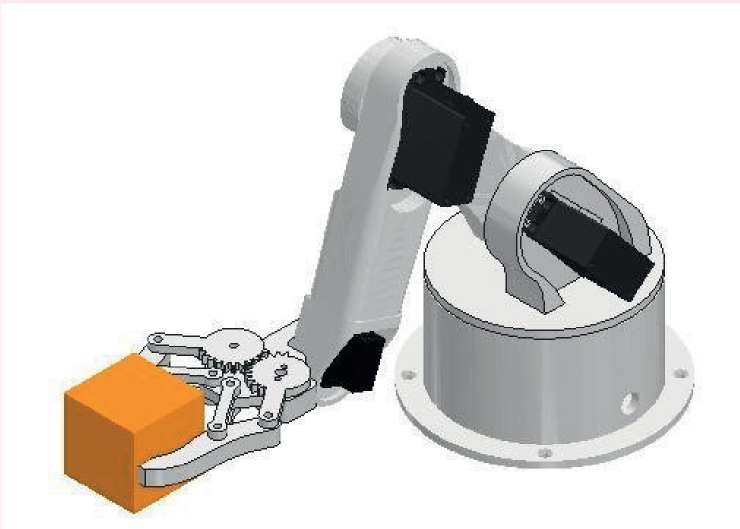

Figure 5. Robotic Arm Dimensions

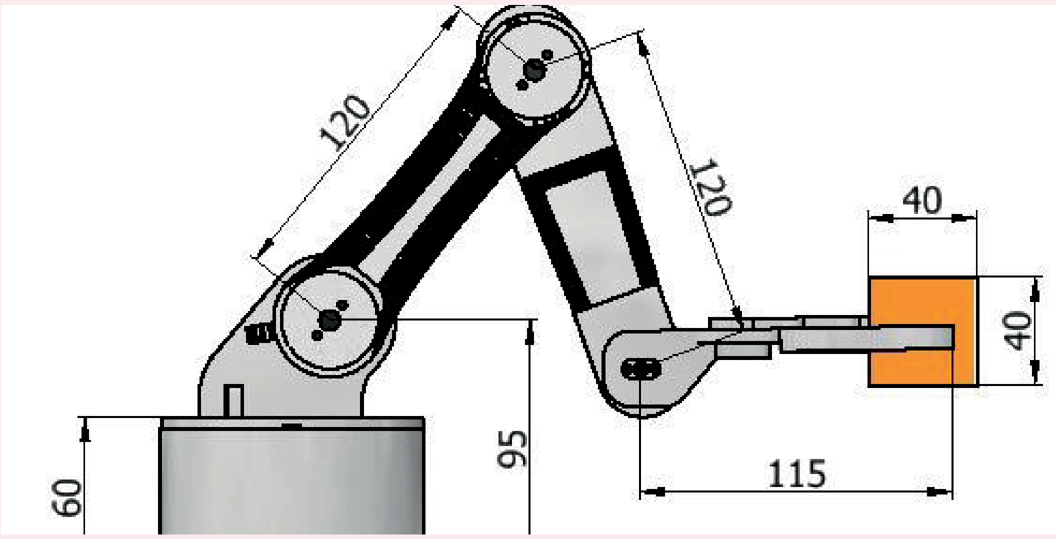

Figure 6. Robotic Arm

ed, and shape classification is conducted based on these parameters. For instance, parameters such as roundness degree, number of corners, and edge lengths facilitate the identification of the object. For a cube, the expectation is eight corners and equal edge lengths, whereas different corner and edge numbers are applicable for a triangular prism.

3.2.4 Shape Classification

Using the data obtained during the feature extraction stage, the shape of the object is classified. This classification is communicated to the microcontroller, enabling necessary decisions for placing the object in the predetermined position.

4. Description of the Project

4.1. Algorithm

- The conveyor belt is activated, the robotic arm is positioned to its home position, and the image processing system is initiated.

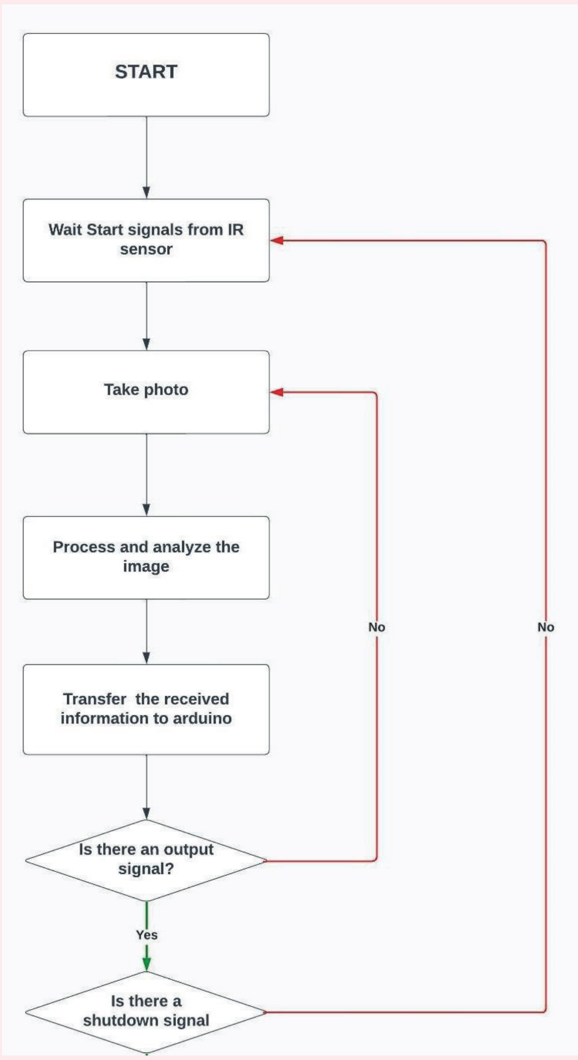

Figure 7. Image Processing Flow Chart

- The IR sensor detects the object coming from the conveyor belt and sends this information to the microcontroller to initiate the process.
- The microcontroller halts the conveyor belt using the information received from the IR sensor.
- The image processing system perceives the color and shape of the object and communicates this information to the microcontroller.
- The microcontroller identifies and places the object on the conveyor belt based on the image processing data.
- After completing the operation, the robotic arm returns to its initial position.
- The conveyor belt is reactivated, continuing the process loop

4.2. Insertion of Artificial Errors and System Response

To assess the accuracy and reliability of the system, specific artificial errors have been introduced. These errors are utilized to demonstrate how the system responds to certain color and shape combinations. Particularly, the system is designed to detect only cubes in red, yellow, and green colors.

When unwanted objects such as a pink cube or a green triangle are introduced to the system, it will not respond to these objects and will not perform any action (Šekoranja Švaco and Jerbić ,2014)

Figure 7 shows the Image Processing Flow Chart, and Figure 8 presents the Robotic Arm Flow Chart.

4.4.1 Pink Cube

Since the system does not recognize the color pink, it will not detect this object, and the conveyor belt will not be stopped.

4.4.2 Green Triangle

The system identifies triangular prisms as faulty shapes during the shape recognition stage. Even though the color green is correct, this object will not be processed due to the shape recognition algorithm.

These artificial errors demonstrate that the system processes only objects that meet the specified criteria and minimizes false positives.

5. Design

5.1. Robotic Arm

The parts of the robotic arm were designed in Autodesk Inventor CAD software. The assembly of the parts in the software is shown in Figure 9.

All components of the robotic arm are intended to be

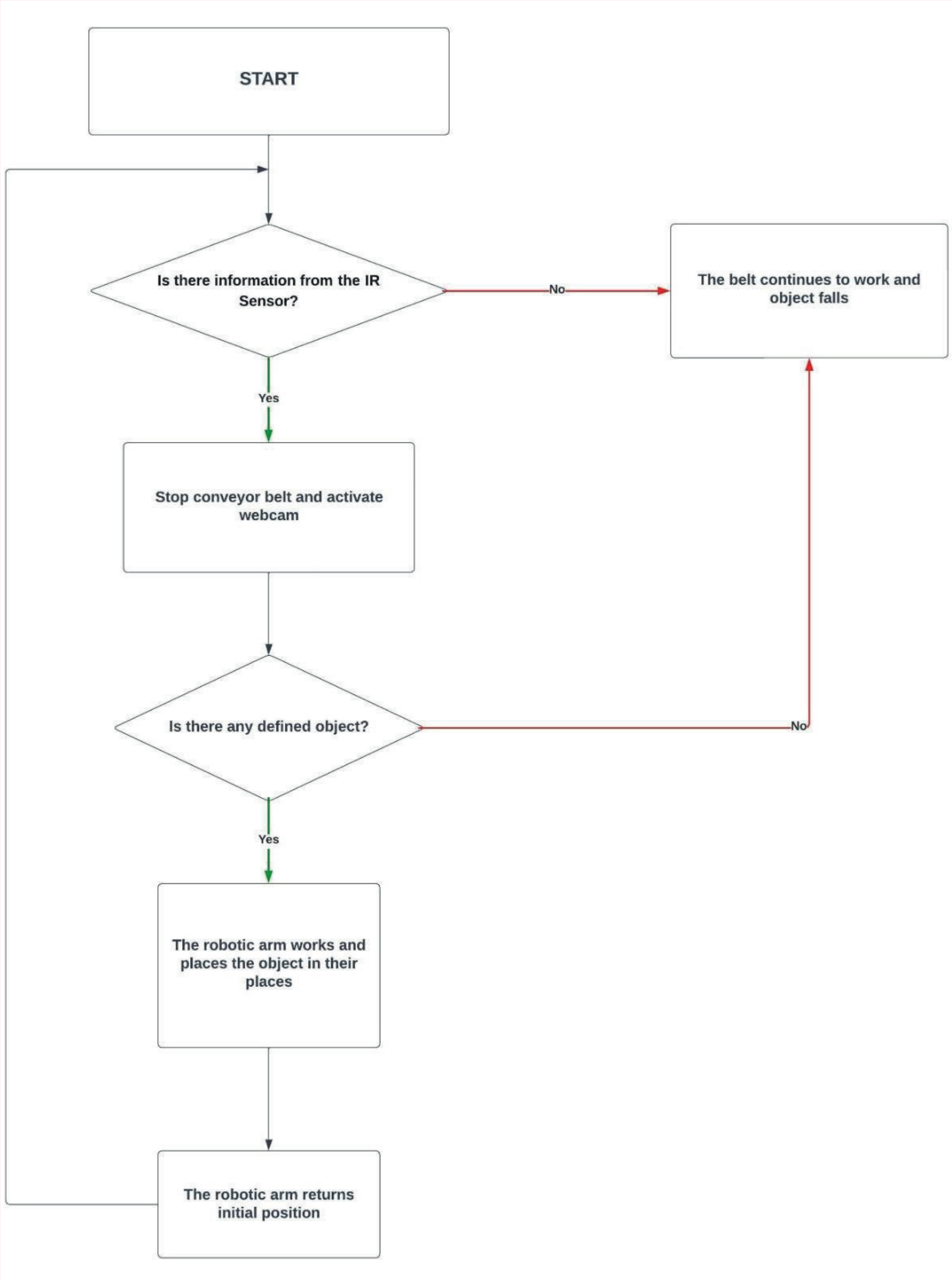

Figure 8. Robotic Arm Flow Chart

Figure 9. Assembly of parts in software

made of PLA thermoplastic. Arm-1, Arm-2, the mounting base, and the holders are fastened to each other at the junctions with the axis of the servo motors. Screws should be used to secure the servo motors and connections to the arms and base. One of the servo motors (MG996), as shown in Figure 10, should be mounted to the base of the robotic arm.

One of the servo motors (MG996) should be placed on the waist of the robot arm as shown in Figure 11.

The servo motor (MG996) attached to the waist should be connected to Arm-1 shown in Figure 12. The other end of arm-1 should be connected to arm-2 using the third servo motor (MG996).

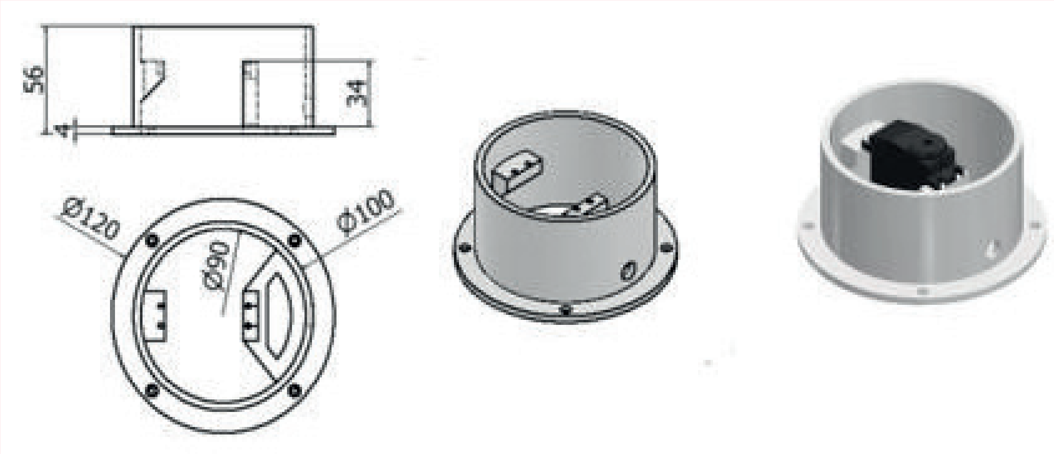

Figure 10. Base of robotic arm

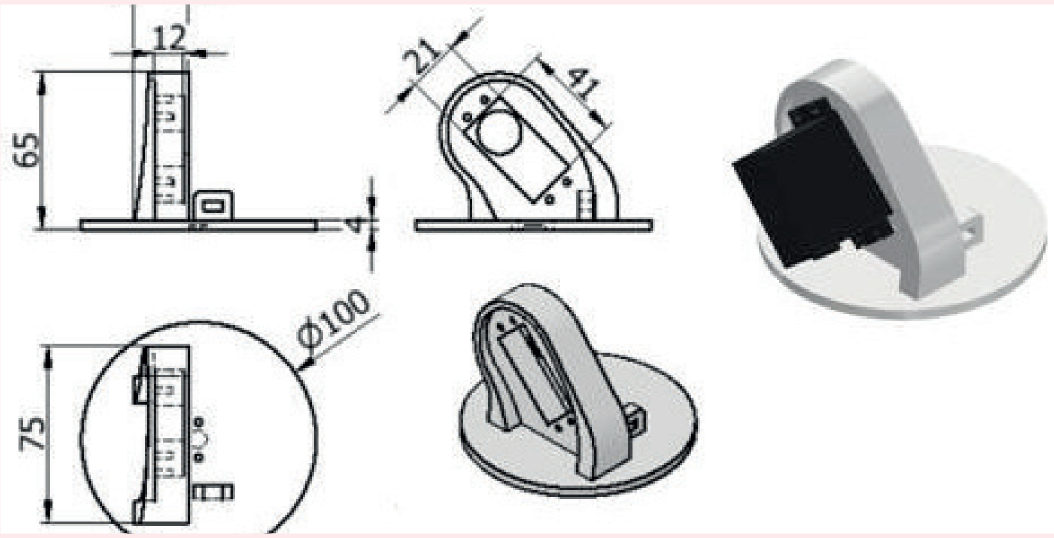

Figure 11. Waist part of the robotic arm

Figure 12. Arm-1 of the Robotic Arm

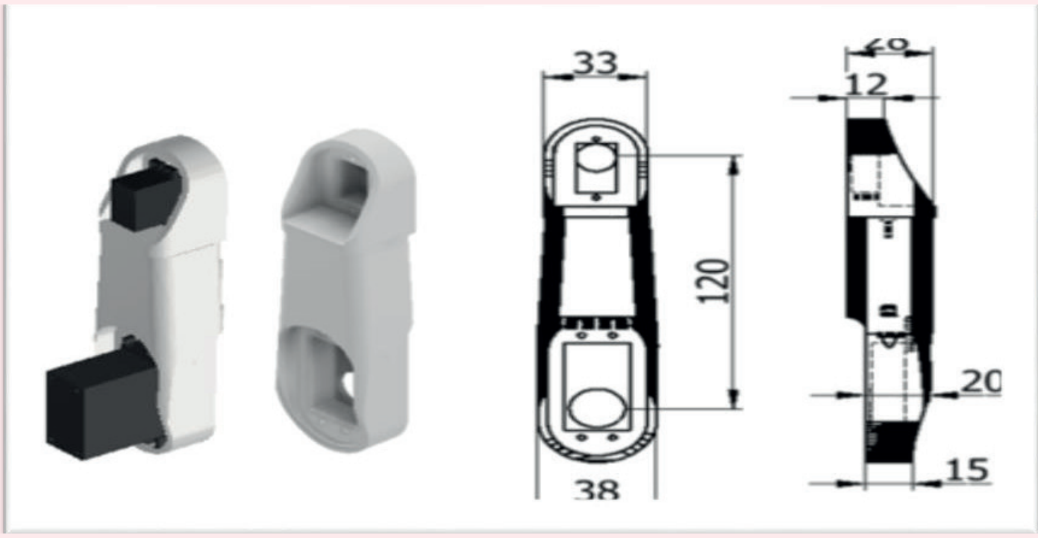

Figure 13. Robot's Arm-2

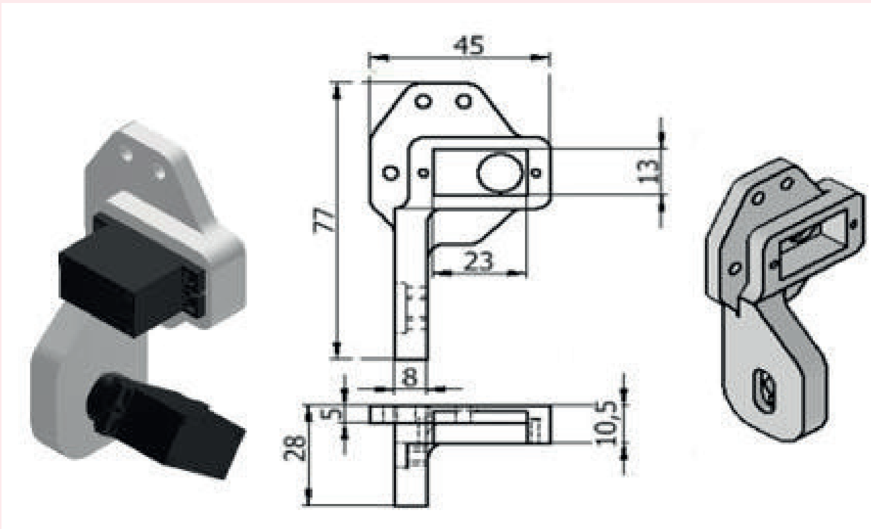

Figure 14. Base of the clutch mechanism

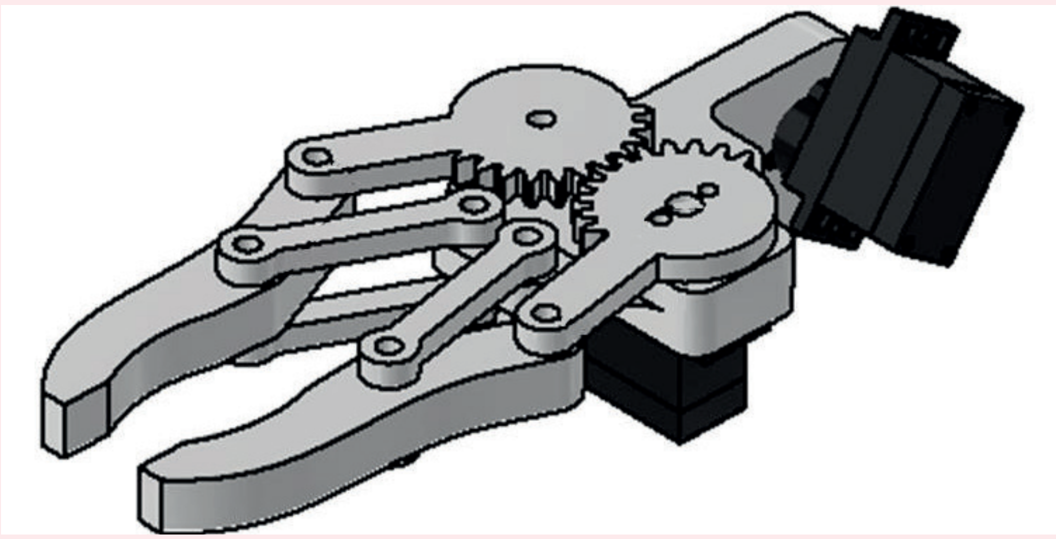

Figure 15. Assembly of the Clutch Mechanism

Arm-2 should be connected to Arm-2 by servo motor (MG996) and to the base of the gripper by servo motor (SG90) as shown in Figure 13. The base of the gripping mechanism must be attached to Arm-2 and one of the gears by means of two servo motors (SG90) as shown in Figure 14.

The gripping mechanism of the robotic arm consists of 9 parts: gripping base, gears (2), links (4), and grippers (2). The assembly and components of the gripping mechanism are shown in Figure 15. and Figure 16. respectively.

5.2. Conveyor Belt

The conveyor mechanism is designed for transporting 40

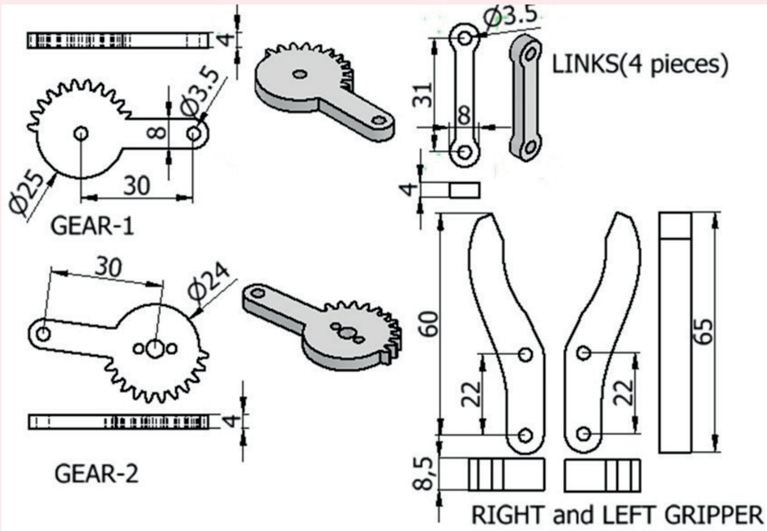

Figure 16. Components of Gripper Mechanism

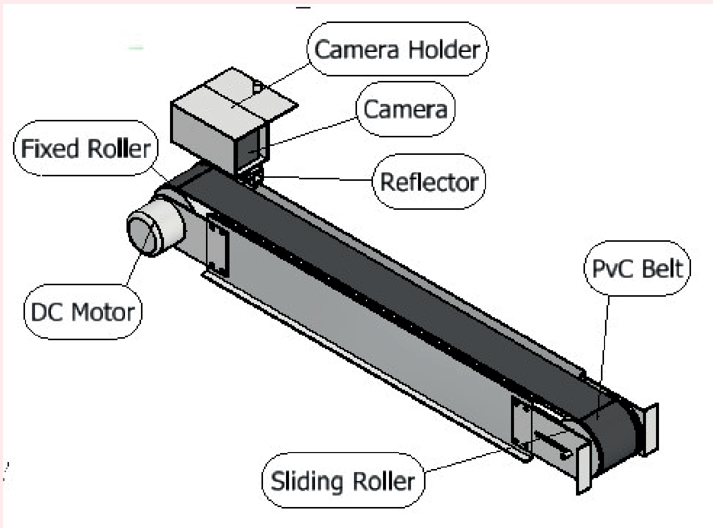

Figure 17. Conveyor and connected components (motor, camera and reflector)

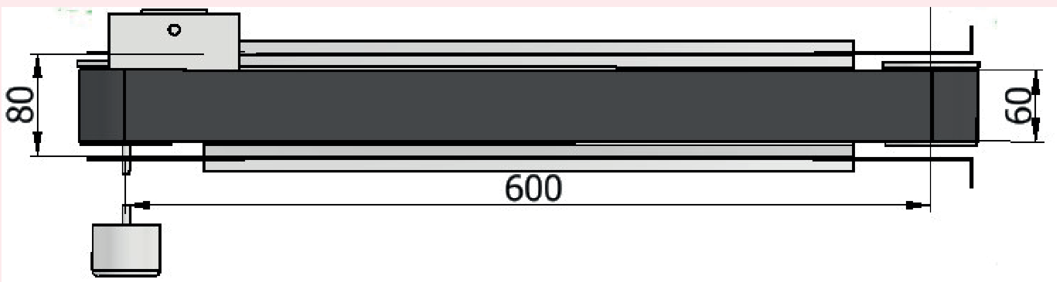

Figure 18. Top view and dimensions of the conveyor

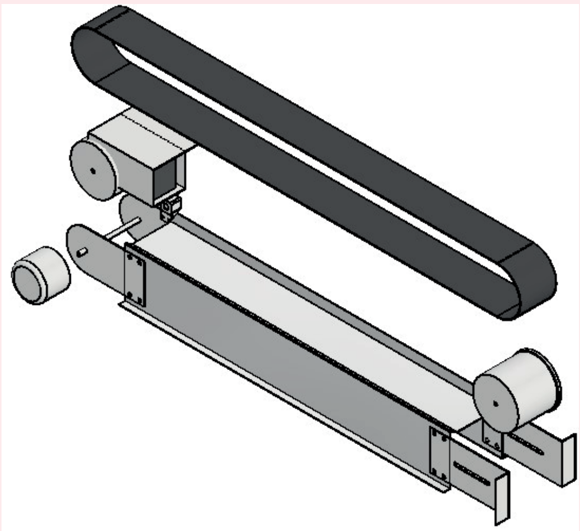

Figure 19. Disassembled view of the conveyor

mm cubes. This mechanism consists of two rollers, two fixtures, and one 12V DC motor, bearings for the rollers and motors, and a PVC flat belt. One of the rollers is in a fixed position, while the other can slide within a socket to adjust the tension of the PVC belt. Additionally, it is planned to install a camera and a reflector to detect the cubes on the conveyor. The body of the conveyor is intended to be manufactured from sheet metal. The components of the conveyor are depicted in Figure 17. and the overall appearance of the conveyor is presented in Figure 18.

The disassembled view of the conveyor is shown in Figure 19.

6. Realistic Constraints

To address the issue of slippage when the gripper holds the object due to being made of the same material, it is planned to use silicone or rubber. To ensure clear perception of color and shape in any environment, LEDs can be placed inside the camera enclosure. To mitigate the complexity arising from the excessive number of cables used in this system, soldering is contemplated. Care should be taken to maintain a sufficient length for the camera enclosure to avoid restricting the movement of the robotic arm.

7. Conclusion

The primary objective of the "COLOR-BASED OBJECT SORTING" idea is to streamline business operations. The proposed project will provide companies with a range of financial advantages. This system will enable accurate and fast production processes, contributing to continuous production and enhancing customer satisfaction, thereby increasing the company's brand value. The scalability of the project is particularly important for businesses; this allows the system to be integrated not only for the mass production of products but also into various other areas such as product packaging, detection of defective or damaged products, warehouse organization, and product assembly.

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